Dyslexia: The Phonology-Reading Disconnection Hypothesis:
Why It Doesn't Tell the Whole Story!

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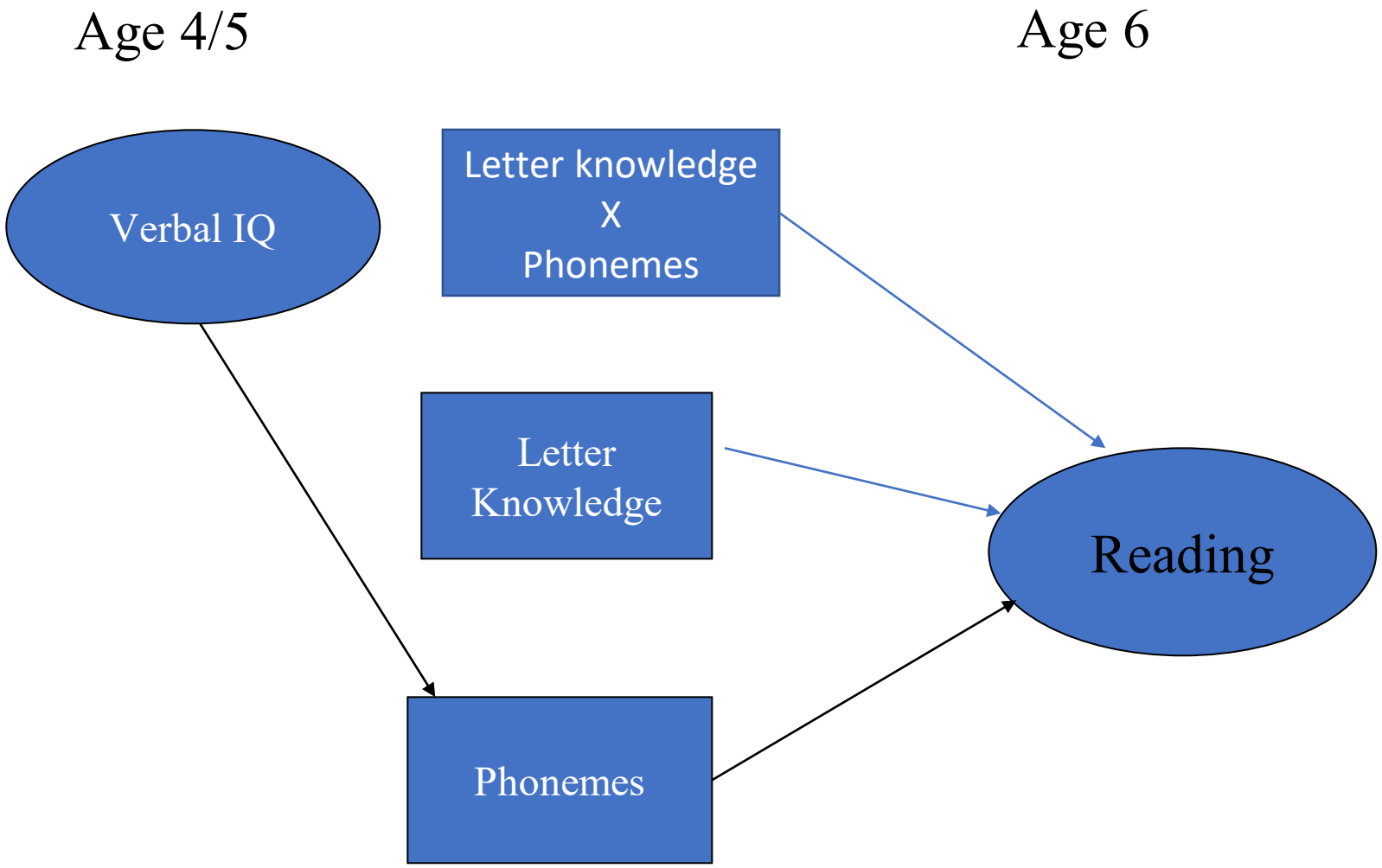
The Phonology-Reading Connection

- Phonological skills – skills that involve dealing with, analysing and processing speech sounds
- Implicit (automatically engaged) phonological *processing* skills – tapped by verbal short-term memory, RAN (rapid automatised naming) and nonword repetition tasks
- Explicit phonological *awareness* skills require children to reflect upon and manipulate the speech sounds in words e.g deleting sounds from words – 'cat' without the /c/ says 'at'
- Correlational and longitudinal studies show a strong relationship between phonological (in particular explicit) skills and ease of learning to read (initially, Wagner & Torgesen, 1990s, and confirmed by multiple studies in the 2000s)

The Phonology-Reading Connection in Typical Early Reading Development

- Muter, Hulme, Snowling & Stevenson (2004)
- 90 children – recruited at age 4y and followed longitudinally to age 6y
- Chartered development of language, phonology and reading during first two years at school
- Phoneme awareness, letter knowledge and the interaction of these 2 skills drive early progress in word level reading skills

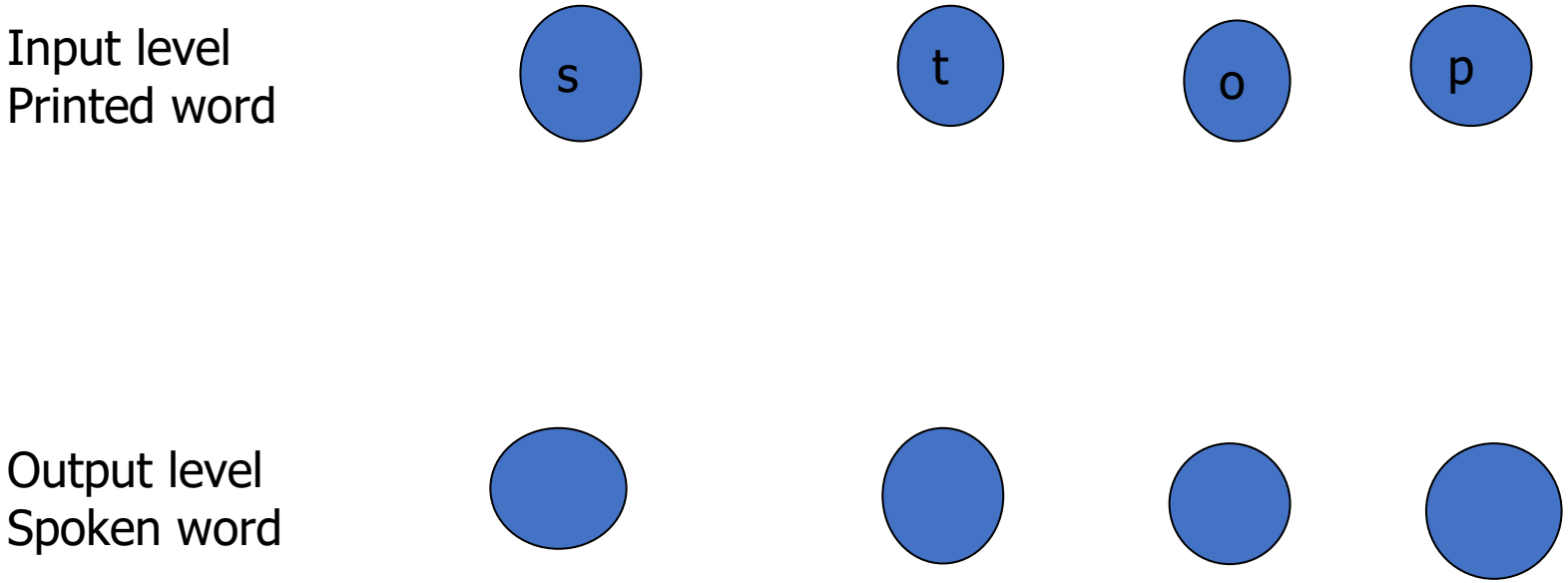
The Phonology-Reading Connection



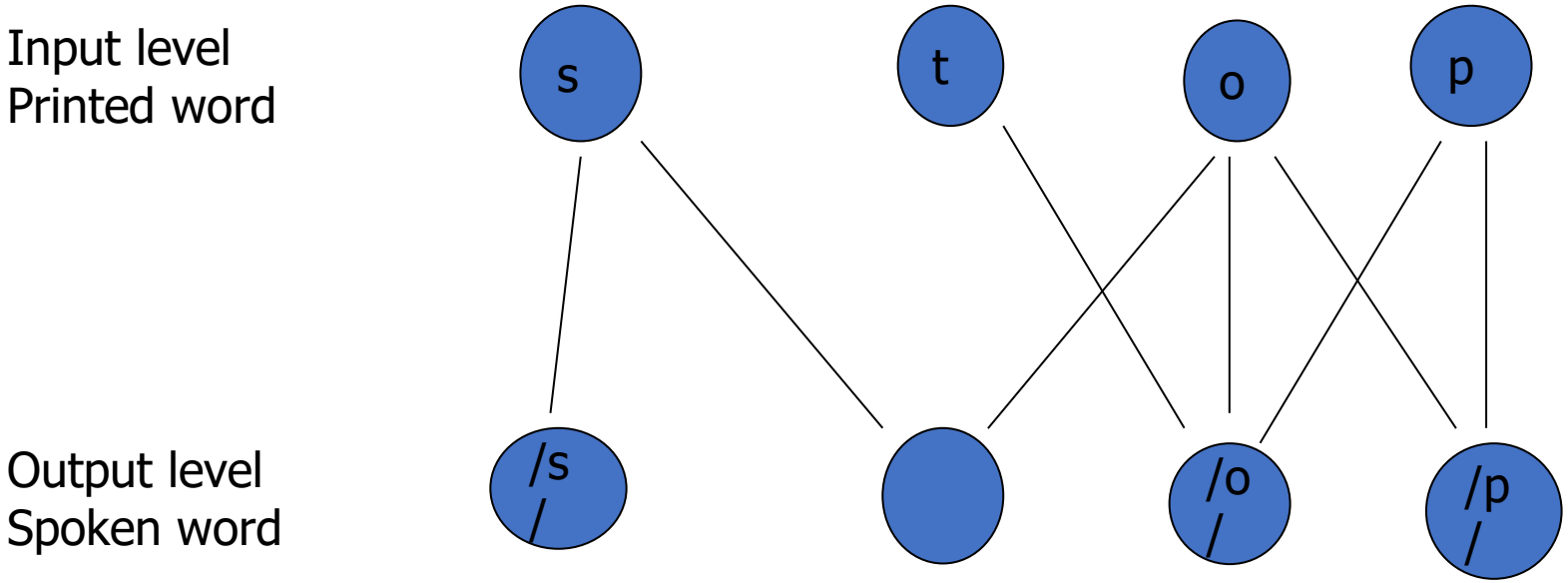
How Computer Models Explain the Phonology-Reading Connection: Seidenberg & McClelland ’89, Plaut ‘96

- Representations of printed words not holistic, but distributed across many simple processing elements in *input* and *output* systems
- **Input** system encodes **letters** & their position in printed words
- **Output** system encodes **phonological** features of word pronunciations
- Patterns of activation across these systems gradually become associated with each other i.e. connections or **‘mappings’** are formed between input (printed letters) and output (sounds) elements
- The strength of these connections is measured as ‘weights’ which gradually become greater with more learning trials
- Achieved through a learning algorithm which alters the weights on the connections in so as to reduce error over learning trials

Before Training:
No mappings evident so word cannot be read



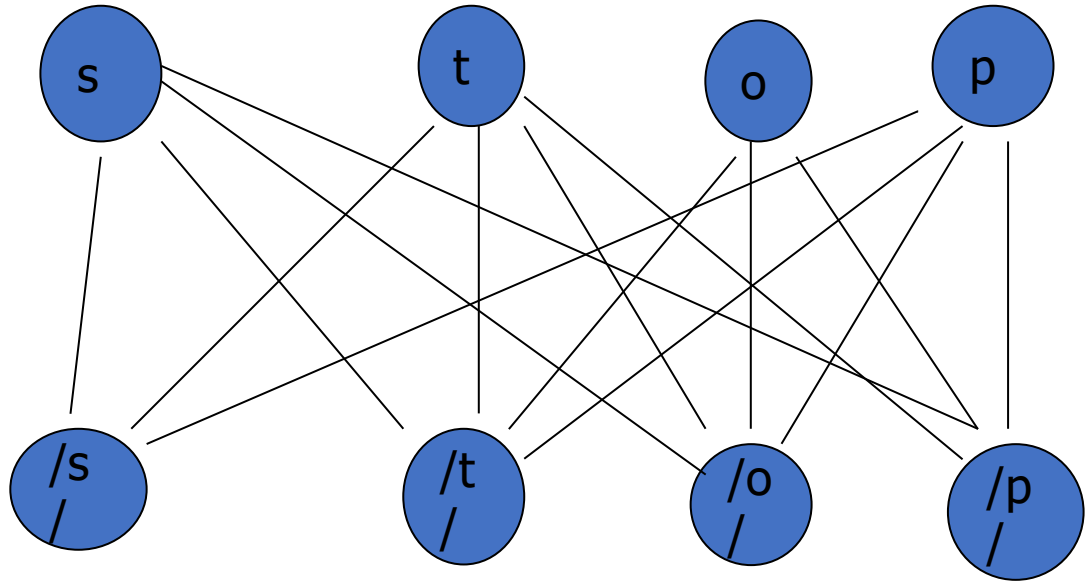
Mid-way Through Training:
Partial mappings emerge so the word may be partly read



End of Training
Full mappings emerge so word read accurately

Input level
Printed word

Output level
Spoken word



A Longitudinal Case Study Demonstrating how Phonology and Reading become *Disconnected* in Dyslexia

- Nicholas participated in a longitudinal study of reading – seen at ages 4, 5, 6 & 10y
- At 4, his scores on phonological & letter knowledge tests were the same as peers – essentially at 'floor'
- At 5: Phoneme Deletion 0/10 (mean of sample 3/10), Letter Knowledge 5/26 (mean of sample 12/26)
- AT 6: Phoneme Deletion 0/10 (5), Letter Knowledge 5/26 (19), BAS Reading Test 5 (17)

Nicholas At Age 10

NARA Reading Accuracy Score 2nd centile

Group Mean	N's score
• Phoneme Deletion 17	4/24
• Speech Rate (wps) 4.8	3.4
• Nonword Reading 15	2/20

Nicholas's profile is consistent with a diagnosis of dyslexia. And provides an excellent example of first, the phonology-reading disconnection and second, how the achievement gap between dyslexic and typical readers is evident from the first year of school and persists and indeed widens towards the secondary school years (Ferrer et al., 2015)

Dyslexia and the Phonology-Reading Disconnection Hypothesis: How Do We Prove It?

- Theory that word level reading problems (dyslexia) are caused by a phonological deficit i.e. in speech sound processing; this causes a disconnection or failure to effectively map phonemes to print
- 2 testable claims follow:
  - Severity of the phonological deficit predicts variations in severity of reading deficit
  - Phonological deficit precedes the reading difficulty
- We know that children with dyslexia perform poorly on a wide range of phonological tasks inc. phoneme awareness, nonword repetition, short-term verbal memory and naming speed compared to age- and reading age-matched controls; in general, the more severe the phonological deficit the more severe the reading problem (see Hulme & Snowling, 2009 for review)

Is the phonological deficit in dyslexia evident before children learn to read?

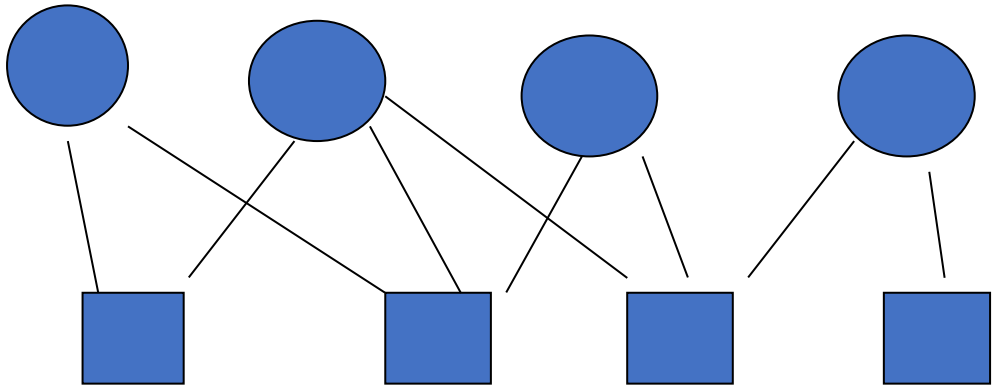
- Hindson et al, 2005, compared language & phonological skills of pre-school children at family risk of dyslexia with those in a control group
- At-risk group had significantly lower scores on measures of phoneme and rhyme awareness, emerging letter knowledge, verbal memory & articulation rate compared to the controls
- The phonological deficit predates the reading problem suggesting a causal connection

How Does the Phonological Deficit Affect Literacy?

- Phonological tasks tap the integrity of the child's phonological representations – these are 'fuzzy' or poorly specified in dyslexic children (Fowler, 1991)
- In computer models, 'fuzzy' phonological representations prevent the development of firm **connections** or **mappings** between sounds & letters
- In effect, poor phonological skills impair development of phonic decoding skills – the **nonword reading deficit** (Rack, Snowling et al, 1992) – and ultimately therefore reading and spelling

Dyslexia – How Phonology-Reading Connections/Mappings are Reduced

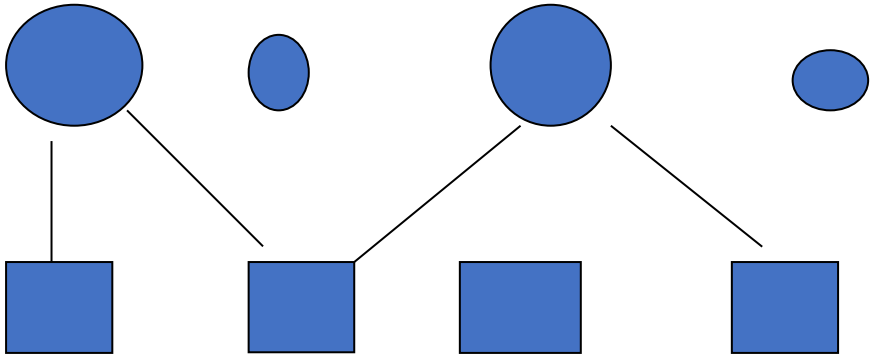
Typical Reader



phonemic representations well specified

letter strings

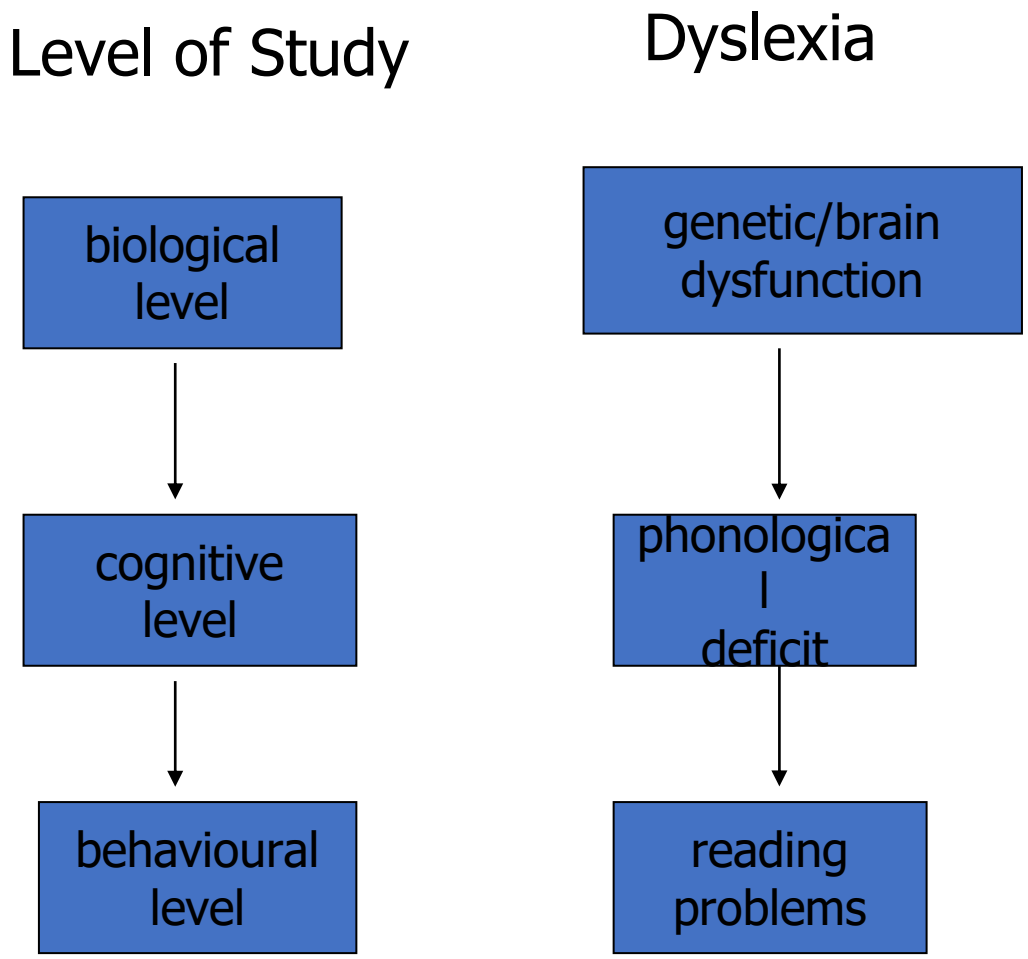
Dyslexic Reader



phonemic representations 'fuzzy'

letter strings

Single Deficit Model of Dyslexia (Frith) Showing the Reading-Phonology Disconnection



Beyond the Single Deficit Disconnection Model: How it Fails at both the Biological & Cognitive Levels

- The single deficit model of dyslexia is based on a **modular** view of brain function i.e. the view that a single specified brain region (and a single set of genes) is responsible for a given cognitive function e.g. phonology (modules are assumed to be separate and independent of each other)
- But imaging studies show that a given cognitive functioning is not located in a single specialised brain region; rather, it depends on connections/interactions a brain region has with other regions
- Also, evidence shows that genes and cognitive deficits are **shared** across disorders i.e. the same genes and cognitive deficits may give rise to more than 1 disorder; they are not separate and independent

Why We Needed the Shift to Multiple Deficit Models (1)

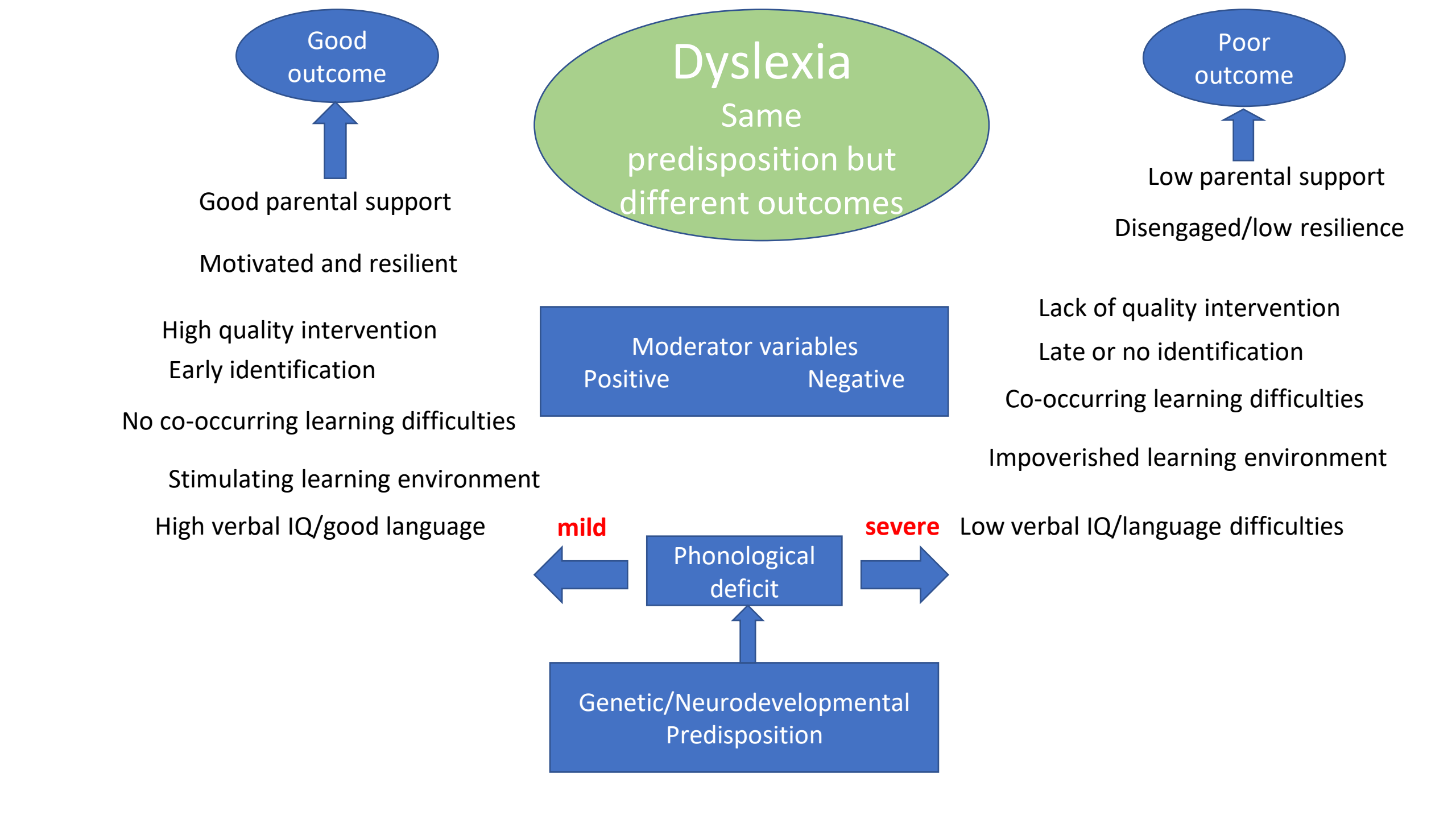
Single deficit models have difficulty explaining:

- Variations in degree of the learning difficulty (dyslexia as a continuum or dimension, ranging from mild through to severe)
- A ‘family at risk’ study in the 1990s (Snowling et al) predicted that children with phonological deficit would have dyslexia, those who didn’t won’t
- **But**, while the at risk children with frank reading problems had phonological difficulty, so did those with who didn’t meet criteria for reading problems (but who nonetheless had spelling and fluency difficulties)
- Suggesting a continuum of severity from mild to severe

Why We Needed the Shift to Multiple Deficit Models (2)

Single deficit models also have difficulty explaining:

- Variations in expression of the learning difficulty; different outcomes are due to interaction of multiple risks or deficits (that are probabilistic) and strengths,
- Child may have multiple risks that accumulate to reach a **threshold** where a diagnosis of a learning difficulty becomes likely (Pennington et al, 2012)
- A phonological deficit *and* oral language deficit will very likely be needed to identify a child with severe dyslexia
- A phonological deficit alone, especially when combined with a verbal strength, is often seen in children with mild dyslexia
- The expression of the learning difficulty can be additionally impacted by **moderator variables** which may be extrinsic/environmental and which can be *positive* e.g. supportive parents, good intervention, or *negative* e.g. uninvolved parents, no intervention; some moderator variables are intrinsic and can again be *positive* e.g. having good oral language, having good resilience, or *negative* e.g. weak oral language, having a low frustration threshold.


Good outcome
Dyslexia
Same predisposition but different outcomes
Poor outcome
Good parental support
Motivated and resilient
Low parental support
Disengaged/low resilience
High quality intervention
Early identification
No co-occurring learning difficulties
Stimulating learning environment
High verbal IQ/good language
Moderator variables
Positive
Negative
Lack of quality intervention
Late or no identification
Co-occurring learning difficulties
Impoverished learning environment
Low verbal IQ/language difficulties
mild
severe
Phonological deficit
Genetic/Neurodevelopmental Predisposition

Why We Needed the Shift to Multiple Deficit Models (3)

Finally, single deficit models have difficulty explaining:

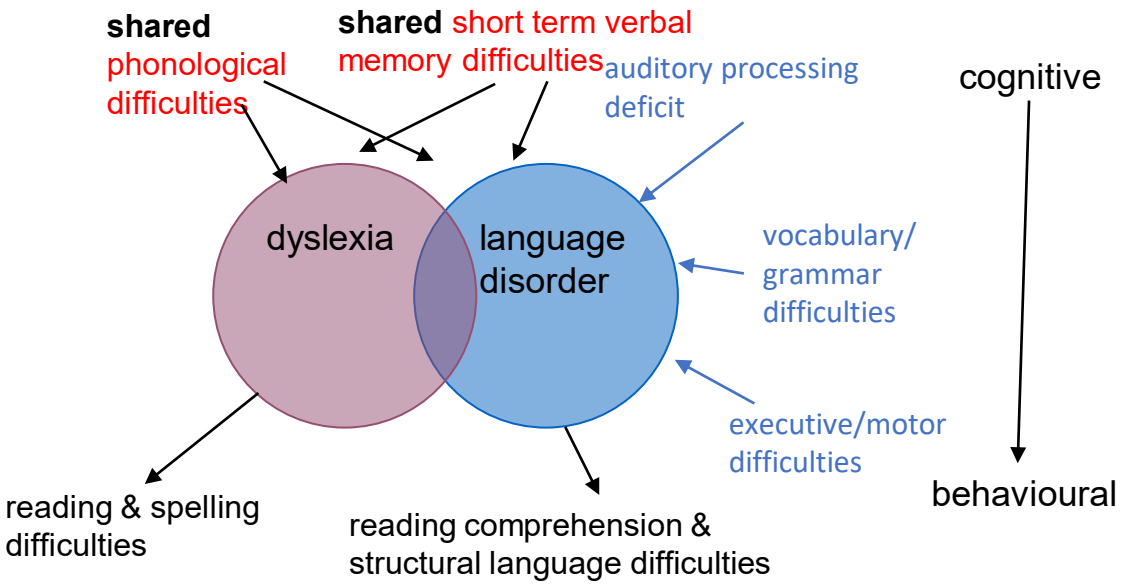
- **Co-occurrence** - 'pure' learning difficulties are the exception; most children have co-occurring learning problems (Caron & Rutter, 1991)
- In a long-term Family At-Risk study (Snowling et al, 2007), 70% of reading impaired children at age 12 had either attention, maths, language or visuomotor difficulties as well (and sometimes more than one of these)
- If modules are separate and independent (as in the Single Deficit Disconnection Model), how can co-occurrence be so common?
- Cognitive risks are *shared* across learning disorders – this is why they co-occur or overlap so frequently
- There are also *non-shared* risks which are specific to a given learning disorder – and which explain the incomplete overlap of two disorders
- A co-occurring difficulty may be a **forerunner** of dyslexia and pre-date it (e.g. with language disorder) or they may **co-exist** at the same time (e.g. with arithmetic disorder, attention disorder, visual motor disorder) – now, let's look at these

Dyslexia and Co-Occurring Language Disorder:

Some Facts about Language Disorders

- 50% of children with delayed or disordered pre-school language development will go on to experience reading difficulties; thus, language difficulties are a common **forerunner** of later reading problems
- However, children who display preschool language problems that resolve by the age of 4-5 years are far less likely to have difficulty learning to read.
- Having poor early language development and being born into a family of poor readers are risk factors for developing reading problems.
- At a practical level, screening pre-schoolers from at-risk families on an early phonological measure (e.g. a nonword repetition test) and a broader language measure (e.g. a sentence repetition test) will enable practitioners to identify children at risk for different forms of language and literacy impairment

Dyslexia and Language Disorder
Shared and Non shared Risks



50% of children with DLD will go on to have a literacy disorder; however, if language difficulties resolve by school age, they are less likely to attract a dyslexic diagnosis

'This is a lovely book! Parents and children can enjoy activities together, including the key building blocks of reading. This book is aimed at children at risk of dyslexia...but it can be recommended for all children.'

Professor Maggie Snowling CBE, President of St John's College, University of Oxford

'I would strongly recommend any educator, specialist teacher or parent to use this book.'

Dr Kevin Smith, Professional Development Co-ordinator of the Professional Association of Teachers of Students with Specific Learning Difficulties

Can you spot Dina Dinaroo and her friends, and see what they have found in the dump? Can they recycle it? Or make something new?

Find out in this special alphabet book which:

- promotes faster progress in language and learning to read
- teaches essential pre-reading foundation skills
- helps children with speech and language difficulties
- encourages an awareness of the environment.

Dr Valerie Muter is a clinical and research psychologist with a special interest in children's early cognitive development, particularly in relation to language and literacy.

Dr Helen Likierman is a clinical child psychologist, parent and former primary school teacher, and has a long-standing interest in problems of waste and pollution.

Jane Dorner is an author and illustrator.

Cover design by Rosamund Bird

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My Special Alphabet Book

Valerie Muter and Helen Likierman

Valerie Muter and Helen Likierman

Illustrated by Jane Dorner

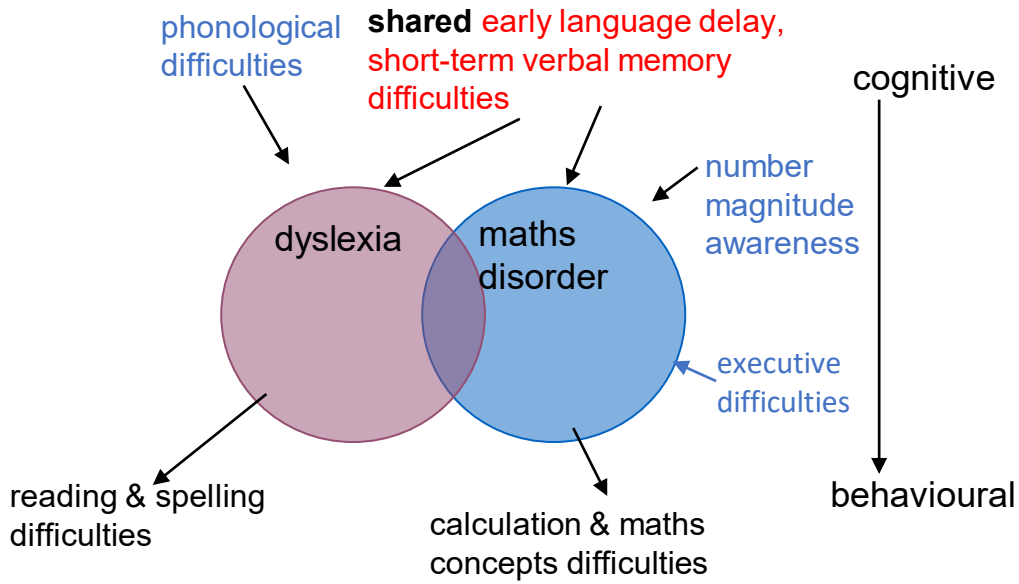
My Special Alphabet Book

Dyslexia and Co-Occurring Arithmetic Disorder: Some Facts about Arithmetic Disorders

- Co-occurrence rate of dyslexia and dyscalculia is 23% (Moll and Landerl, 2010)
- Landerl, Moll et al (2016) compared 4 matched groups of children – 'pure' dyslexics, 'pure' dyscalculics, co-occurrers and controls
- Dyslexics had phonological difficulties, as did co-occurrers, dyscalculics did not
- Dyscalculics had problems of *numerosity* (appreciation of the magnitude of number) as did co-occurrers (but not dyslexics), measured by dot and digit comparison and count the dot tasks
- Shared risk factor likely to be verbal language (including verbal working memory, VWM) deficits; non shared factors are phonology (in dyslexia) and numerosity and possibly executive skill (in dyscalculia)
- Note that weak VWM can impact mental maths accuracy and retention of number facts
- And spatial/perceptual difficulties can impair visual maths skills e.g. geometry, symmetry

Dyslexia and Arithmetic Disorder

Shared & Non-shared Risks: A Proposed Model



23% overlap of literacy and arithmetic disorders

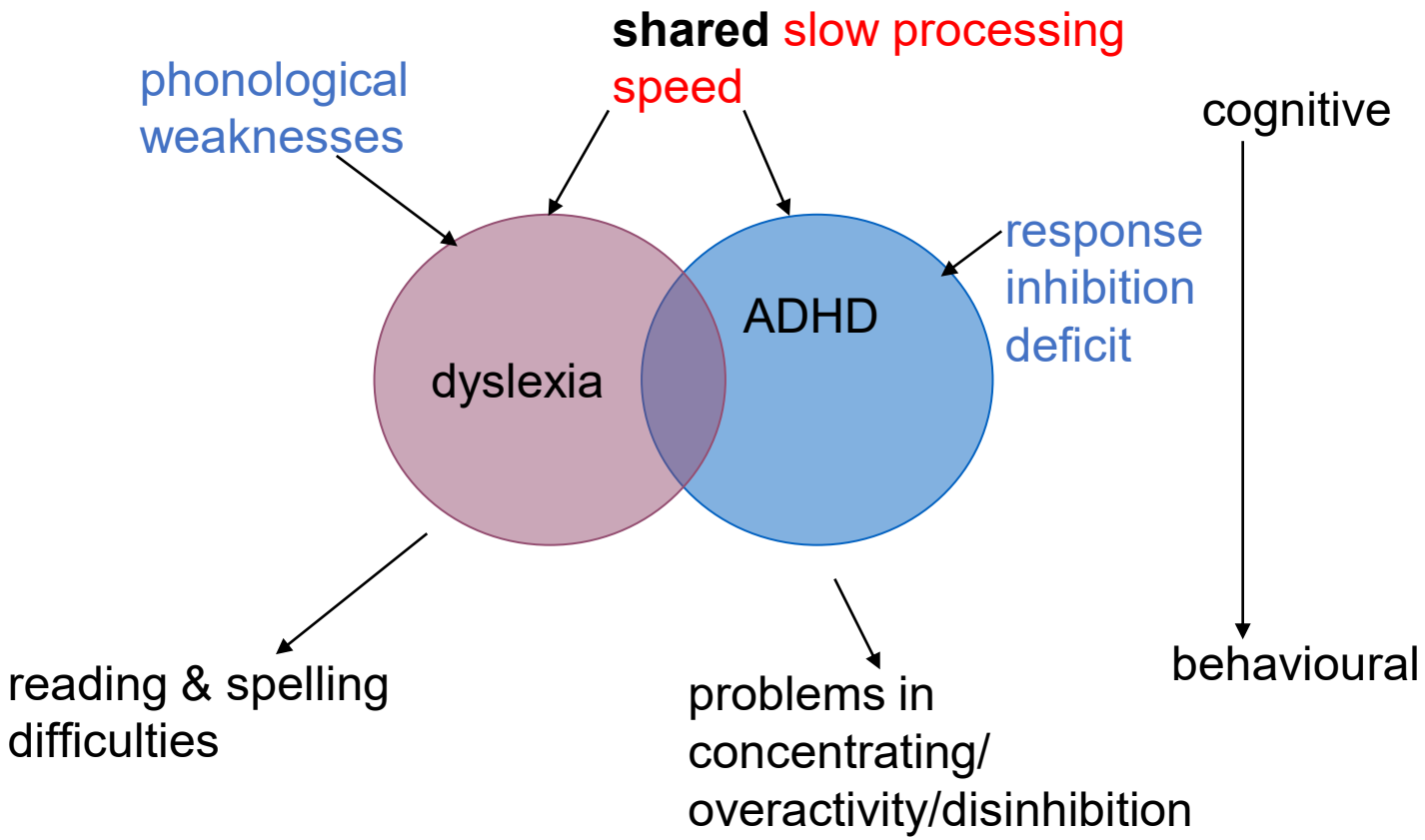
Dyslexia and Co-Occurring ADHD: Some Facts about ADHD

- Gooch et al (2011) compared the cognitive performance of children with dyslexia only, children with ADHD symptoms, children with both dyslexia and ADHD symptoms (co-occurrers) on:
- Three separate tasks – phonological tasks (e.g. phoneme deletion, nonword repetition), executive skills (e.g. sustained attention & working memory), and time perception (e.g. estimating time durations)
- Children with dyslexia performed poorly on the phonological tasks, the children with ADHD on the executive and time perception tasks, and the children with both disorders on all three tasks.
- McGrath et al (2011) demonstrated that the non shared executive skill deficit in co-occurring dyslexia and ADHD is response inhibition, while the shared deficit is slow processing speed
- Co-occurrence rate of dyslexia and attention disorders of 25-40%

Dyslexia and Attention Deficit Disorder

Shared & Non-shared Risks

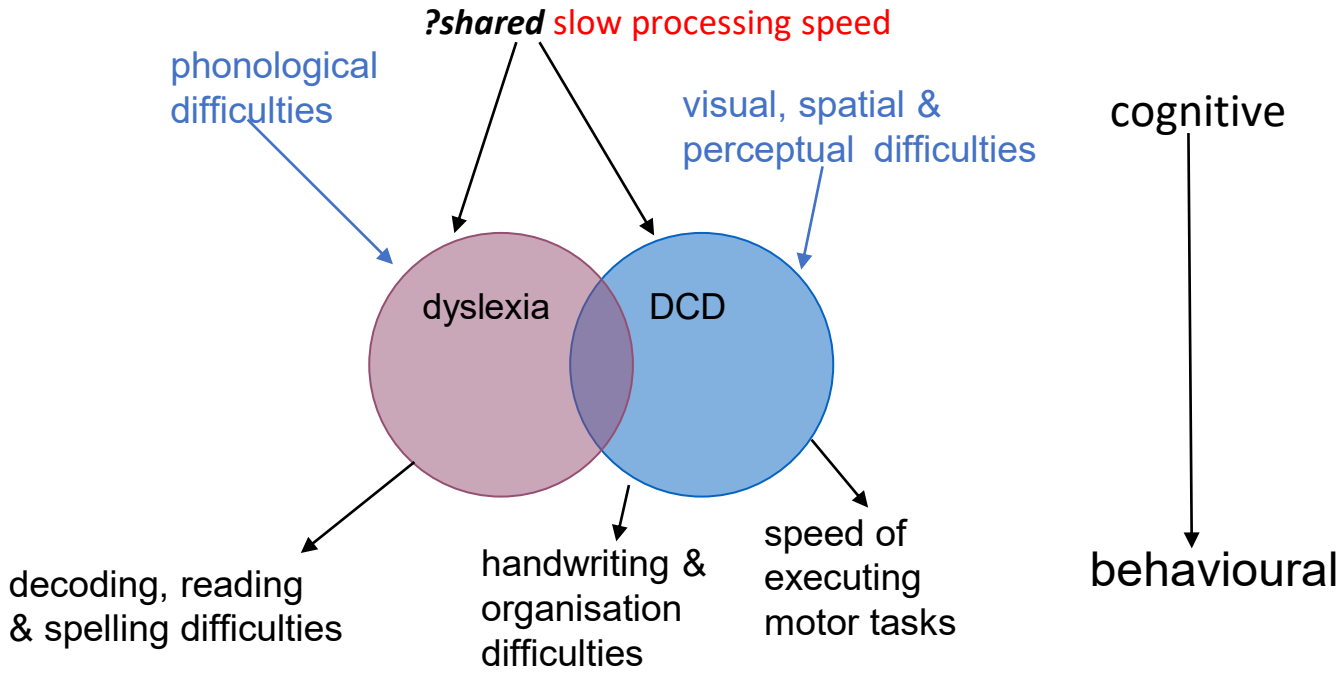
McGrath, Pennington et al, 2011



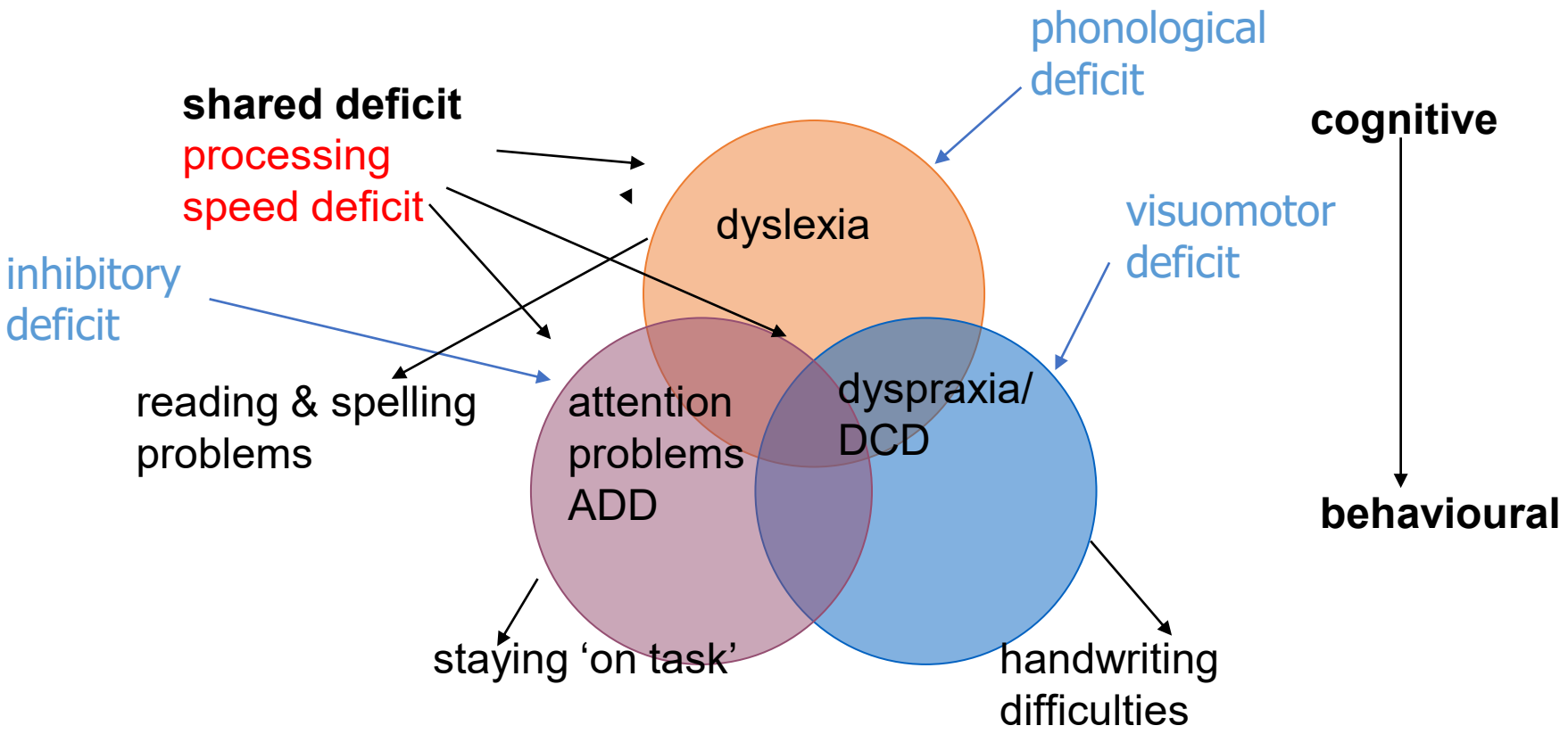
Dyslexia and Co-Occurring DCD/Dyspraxia: Some Facts about DCD/Dyspraxia

- Nearly 60% of children with dyslexia have co-occurring perceptual-motor problems that impact their handwriting speed and quality, and their written presentation and organisation (Ramus et al, 2003)
- Cognitive deficit in DCD may be a 'noisy sensorimotor map' – difficulty in processing spatial information within the visual modality; this means that visual information about spatial location is 'blurred, resulting in difficulty in producing movements that are guided accurately in space (Hulme & Snowling, 2009)
- Seems obvious that the non-shared deficits explaining incomplete overlap are phonology (dyslexia) and visual/spatial/perceptual function (DCD).
- What is shared deficit explaining co-occurrence? Slow processing speed (often viewed as a 'domain general deficit') is one potential candidate.
- Or does, the shared-/non-shared deficit model not work so well for dyslexia and co-occurring DCD? Would a generalised neurodevelopmental immaturity better explain the co-occurrence (Frith)? Clearly, need for more research.

Dyslexia and Developmental Co-ordination Disorder (DCD) – Shared & Non-Shared Risks



A Complex Specific Learning Difficulty: Dyslexia, Attention Problems and Dyspraxia/DCD



Is processing speed, the shared deficit here, a 'domain general' deficit?

A Complex SpLD – Dyslexia, Attention Problems and Dyspraxia/DCD - Formulation

- A child with a complex specific learning difficulty that comprises:
  - **Developmental dyslexia** that is associated with phonological processing and decoding deficits that impact his development of word level reading and spelling skills
  - Together with co-occurring **visual motor problems** that have impaired his handwriting and
  - **attention problems** that reduce his ability to remain 'on task' and to complete prescribed educational tasks
  - **Shared deficit** that explains **co-occurrence** of the three disorders is **processing speed deficit**
  - **Non shared deficits** are **phonology (dyslexia), visual motor difficulties (DCD)** and **response inhibition (ADD)**

Take Away Messages

- The phonology-reading disconnection in dyslexia is an important and well founded explanation for why children with dyslexia find word level reading difficult
- However, it does not explain the whole story – many dyslexic children have multiple risk factors that go beyond a phonological deficit; also, co-occurrence of dyslexia with other learning disorders is the rule rather than the exception
- The more risk factors and/or co-occurring difficulties the child has, the greater the **cognitive overload** (an expression we're hearing more of) and the more complex and arguably the more severe their educational presentation
- Important, however not to lose sight of 'moderator variables' which may be positive or negative, inherent within the child or extrinsic (environmental) and which can massively influence outcome

Everything practitioners need to know **about the assessment and management of literacy disorders in children**